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In the application of: Ryuji Nishikawa et. al Serial No. 10/758,598 Filing Date: January 16, 2004 For: LASER REPARING METHOD OF ELECTROLUMINESCENT DISPLAY DEVICE	Examiner: LIN, JAMES Group Art Unit: 1762

DECLARATION OF NORIKO KOMORIYA

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Sir:

Noriko Komoriya declares under penalty of perjury under the laws of the United States of America as follows:

1. I am a citizen of Japan currently employed at Suto International Patent Office in Ota-shi, Gunma-ken, Japan. I have a good command both in English and Japanese languages.

2. I have translated Japanese Patent Application No.2003-012381, and the translation is a literal translation of the Japanese patent application.

I declare under penalty of perjury under the laws of the United Stares that the foregoing is true and correct. Executed at Ota-shi, Gunma-ken, Japan, this 18th day of September, 2007.

Noriko Komoriya

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[Title of the Invention] Laser repairing method of EL display device

[Claims]

[Claim 1]

A method of repairing an EL display device using laser, the device comprising a plurality of pixels each including an EL element having an EL layer formed between an anode layer and a cathode layer, comprising:

detecting a foreign substance adhering to the EL element; and

irradiating with a laser beam a peripheral region of the foreign substance so that a high resistivity region is formed between the anode layer and the cathode layer of the pixel having the foreign substance.

[Claim 2]

The method of claim 1, wherein the laser beam irradiation is repeated a plurality of times at peripheral regions near the foreign substance.

[Claim 3]

The method of claim 1 or 2, wherein a wavelength of the laser beam for the laser beam irradiation is 532 nm or lower.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The invention relates to a laser repairing method of an electroluminescent display device having a plurality of pixels and an electroluminescent element provided in each of the pixels and formed by interposing an electroluminescent layer between an anode layer and a cathode layer.

[0002]

[Background Art]

An organic electroluminescent (hereafter, referred to as EL) display device using organic EL elements is receiving an attention as a new display device substituted for a CRT or an LCD.

[0003]

Fig. 5 is a cross-sectional view showing a structure of such an organic EL element. An anode layer (ANODE) 1 made of ITO is formed on a transparent insulating substrate 10 such as

a glass substrate, and an organic EL layer formed of a hole transport layer (HTL) 2, an emissive layer (EML) 3, and an electron transport layer (ETL) 4 is laminated thereon. A cathode layer (CATHODE) 5 is formed on this organic EL layer. A potential difference is applied between the anode layer 1 and the cathode layer 5. When a drive current flows in the organic EL element, a hole injected from the anode layer 1 and an electron injected from the cathode layer 5 are recombined in the emissive layer 3, and an organic molecule forming the emissive layer 3 is excited to form an exciton. Light is emitted from the emissive layer in a process of radiation of the exciton and then released outside after going through the transparent anode layer 1 to the transparent insulating substrate, thereby completing light-emission.

[0004]

The above organic EL layer and the cathode layer 5 are formed by a vapor deposition method using a metal mask. In this vapor deposition process, a foreign substance 6 sometimes adheres to a region for the formation of the organic EL element. This generates a short circuit between the anode layer 1 and the cathode layer 5 so that a potential difference disappears between the anode layer 1 and the cathode layer 5. Then, the drive current does not flow in the organic EL element, and a so-called dark spot occurs in this pixel region.

[0005]

To solve this problem, laser beams having a predetermined wavelength (for example, 1056 nm) are radiated to the foreign substance 6 to burn it out. This enables normal light-emission at a peripheral pixel region except the pixel irradiated with the laser beams.

The relevant technology is disclosed in the following patent document 1.

[Patent Document 1]

Japanese Patent Application Publication No.2000-195677

[0006]

[Problem to be solved by the Invention]

However, when the laser beams are not properly radiated to the foreign substance 6, the cathode layer 5 or the like is damaged by the energy of the laser beams and can be torn to form a pin hole at the organic EL element. Once the pin hole is formed, moisture enters the organic EL element therefrom to damage the element, resulting in a display defect of a dark spot.

[0007]

The invention is directed to providing a laser repairing method of an EL display device preventing a pin hole.

[0008]

[Means for solving the Problems]

The invention provides a method of repairing an EL display device using laser, the device including a plurality of pixels each including an EL element having an EL layer formed between an anode layer and a cathode layer, including: detecting a foreign substance adhering to the EL element; and irradiating with a laser beam a peripheral region of the foreign substance so that a high resistivity region is formed between the anode layer and the cathode layer of the pixel having the foreign substance.

[0009]

In the invention, laser beams are configured not to directly incident on the foreign substance, but to be incident on the peripheral region of the foreign substance. This prevents the organic EL element having the foreign substance from being damaged. By irradiating the peripheral region of the foreign substance with laser beams, the energy of the laser beams is also supplied to the foreign substance indirectly. Therefore, by arranging the laser irradiation region properly, the high resistivity region can be formed between the anode layer and the cathode layer and a defective portion caused by a short circuit due to the foreign substance can be repaired.

[0010]

[Description of the Invention]

Next, an embodiment of the invention will be described with reference to the drawings in detail. An organic EL display device of the invention will be described first. Fig. 1 is a plan view showing a pixel of the organic EL display device of the invention. Fig. 2(a) is a cross-sectional view along line A-A of Fig. 1, and Fig. 2(b) is a cross-sectional view along line B-B of Fig. 1.

[0011]

As shown in Figs. 1 and 2, a pixel 115 is formed in a region enclosed with a gate signal line 51 and a drain signal line 52. A plurality of the pixels 115 is arranged in a matrix configuration.

[0012]

An organic EL element 60 as a self-emissive element, a switching TFT 30 for controlling a timing of supplying an electric current to the organic EL element 60, an organic EL element driving TFT 40 for supplying an electric current to the organic EL element 60, and a storage capacitor 56 are disposed in the pixel 115.

[0013]

The switching TFT 30 is provided on a periphery of the intersection of the signal lines 51 and 52. A source 33s of the switching TFT 30 serves as a capacitor electrode 55 for forming a capacitor with a storage capacitor electrode line 54 and is connected with a gate electrode 41 of the organic EL element driving TFT 40. A source 43s of the organic EL element driving TFT 40 is connected with the anode layer 61 of the organic EL element 60, while a drain 43d is connected with a driving source line 53 as a current source for the organic EL element 60.

[0014]

The storage capacitor electrode line 54 is placed in parallel with the gate signal line 51. The storage capacitor electrode line 54 is made of chromium and so on and forms a capacitor by storing an electric charge with the capacitor electrode 55 connected to the source 33s of the TFT 30 through a gate insulating film 12. The storage capacitor 56 is provided for storing voltage applied to the gate electrode 41 of the EL element driving TFT 40.

[0015]

The organic EL display device is formed by laminating the TFTs and the organic EL element sequentially on a substrate 10, such as a substrate made of a glass or a synthetic resin, a substrate having conductivity, or a semiconductor substrate. When using a substrate having conductivity or a semiconductor substrate as the substrate 10, however, an insulating film made of SiO_2 or SiN is formed on the substrate 10, and then the first and second TFTs and the organic EL element are formed thereon. Each of the TFTs has a so-called top gate structure in which a gate electrode is placed above an active layer with a gate insulating film being interposed therebetween.

[0016]

The structure of the switching TFT 30 will be described first.

[0017]

As shown in Fig. 2(a), an amorphous silicon film (hereafter, referred to as an a-Si film) is formed on the insulating substrate 10 made of silica glass or a non-alkali glass by a CVD method

and so on. The a-Si film is irradiated with laser beams for melting and recrystalizing to form a poly-silicon film (hereafter, referred to as a p-Si film) as an active layer 33. On the active layer 33, a single-layer or a multi-layer having an SiO_2 film and an SiN film is formed as the gate insulating film 12. There are formed on the gate insulating film 12 the gate signal line 51 made of a metal having a high melting point, such as Cr or Mo, and also serving as a gate electrode 31, the drain signal line 52 made of Al, and the driving source line 53 made of Al and serving as a driving source of the organic EL element.

[0018]

An interlayer insulating film 15 formed by laminating an SiO_2 film, an SiN film and an SiO_2 film in this order covers the whole surfaces of the gate insulating film 12 and the active layer 33. A drain electrode 36 is provided by filling a contact hole provided above the drain 33d with a metal such as Al. Furthermore, a planarization insulating film 17 for planarizing a surface, which is made of an organic resin, is formed on the whole surface.

[0019]

Next, the structure of the organic EL element driving TFT 40 will be described. As shown in Fig. 2(b), an active layer 43 formed by poly-crystalizing an a-Si film by irradiating the film by laser beams, the gate insulating film 12, and the gate electrode 41 made of a metal having a high melting point, such as Cr or Mo, are formed sequentially on the insulating substrate 10 made of silica glass, or a non-alkali glass. A channel 43c, a source 43s, and a drain 43d are provided in the active layer 43. The source 43s and the drain 43d are placed on both sides of the channel 43c.

[0020]

The interlayer insulating film 15 having the SiO_2 film, the SiN film and the SiO_2 film is formed on the whole surfaces of the gate insulating film 12 and the active layer 43. The driving source line 53 is connected to a driving source by a contact hole filled with a metal such as Al provided on the drain 43d. Furthermore, a planarization insulating film 17 for planarizing the surface, which is made of, for example, an organic resin is formed on the whole surface. A contact hole is formed in a position corresponding to a source 43s in the planarization insulating film 17. A transparent electrode made of ITO and being in contact with the source 43s through the contact hole, i.e., the anode layer 61 of the organic EL element, is formed on the

planarization insulating film 17. The anode layer 61 is formed in each of the pixels as an isolated island.

[0021]

The organic EL element 60 has a structure of laminating sequentially the anode layer 61 made of a transparent electrode such as ITO (Indium Tin Oxide), a hole transport layer 62 including a first hole transport layer made of MTDATA (4,4-bis(3-methylphenylphenylamino) biphenyl) and a second hole transport layer made of TPD (4,4,4-tris(3-methylphenylphenylamino)triphenylanine), an emissive layer 63 made of Bebq2 (bis(10-hydroxybenzo[h]quinolinato)beryllium) containing a quinacridone derivative, an electron transport layer 64 made of Bebq2, and a cathode layer 65 made of a magnesium-indium alloy, aluminum or an aluminum alloy.

[0022]

A second planarization insulating film 66 is formed on the planarization insulating film 17. This second planarization insulating film 66 is removed above the anode layer 61.

[0023]

In the organic EL element 60, a hole injected from the anode layer 61 and an electron injected from the cathode layer 65 are recombined in the emissive layer, and an exciton is formed by exciting an organic module forming the emissive layer. Light is emitted from the emissive layer in a process of radiation of the exciton and then released outside after going through the transparent anode layer 61 to the transparent insulating substrate, thereby completing light-emission.

[0024]

Next, a laser repairing method of the above described organic EL display device will be described. As shown in Fig. 3, a foreign substance 100 is now detected adhering to the organic EL element 60 of one pixel. A cross-section of the structure shown in Fig. 3 is similar to that shown in Fig. 6. As a method of detecting a foreign substance, for example, visual observation using a microscope or an automatic detecting method by a foreign substance detecting device can be employed.

[0025]

In the invention, laser beams are configured not to directly incident on the foreign substance 100, but to be incident on an irradiation region 111 near the foreign substance 100.

This prevents the organic EL element 60 having the foreign substance 100 from being damaged and thus prevents a pin hole formation. By irradiating with the laser beams the irradiation region 111 at a predetermined distance from the foreign substance 100, the energy of the laser beams spreads concentrically from the irradiation region 111, and is also supplied to the foreign substance 100 indirectly. By arranging the irradiation region 111 so as to form a high resistivity region 112 shown by a broken line in Fig. 3, the high resistivity region can be formed between the anode layer 61 and the cathode layer 65, so that a defective portion caused by a short circuit due to the foreign substance 100 can be repaired. This high resistivity region is formed because the hole transport layer 2, the emissive layer 3 and the electron transport layer 4 are melted together by thermal energy of the laser beams and thus the layered structure thereof disappears.

[0026]

Here, a commercially available YAG laser (for example, having a laser wavelength of 355 nm) can be used as the laser source. The size of the irradiation region 111 is 5 μm by 5 μm, for example. The size of the foreign substance 100 is 0.3 μm to 10 μm. It is preferable to set the irradiation region 111 at a distance of 5 μm to 10 μm from the foreign substance 100.

[0027]

When the size of the foreign substance 100 is 3 μm or more, it is preferable to supply a large amount of energy to the region of the foreign substance by positioning the laser beams to four peripheral regions of the foreign substance 100, that is, a left side, an upper side, a right side and a lower side (I to IV in Fig. 4) of the foreign substance 100, as shown in Fig. 4. The number of the multiple irradiation can be increased or decreased as appropriate based on the size of the foreign substance 100.

[0028]

It is noted that the laser beams having a wavelength of 532 nm or lower can repair the defective portion without damaging the organic EL element.

[0029]

[Effect of the Invention]

In the laser repairing method of the EL display device of the invention, laser beams are configured not to directly incident on the foreign substance, but to be incident on the peripheral region of the foreign substance. This prevents a pin hole formation which causes a dark spot and

a defective portion caused by a short circuit can be repaired. This repairs a display defect and enhances the yield of the EL display device.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is a plan view of an EL display device for the invention.

[Fig. 2]

Fig. 2 shows plan views of the EL display device for the invention.

[Fig. 3]

Fig. 3 is a plan view for explaining a laser repairing method of an EL display device of an embodiment of the invention.

[Fig. 4]

Fig. 4 is a plan view for explaining the laser repairing method of the EL display device of the embodiment of the invention.

[Fig. 5]

Fig. 5 is a cross-sectional view of a conventional organic EL element.

[Fig. 6]

Fig. 6 is a cross-sectional view of the conventional organic EL element.

[Description of Numerical]

60 organic EL element

100 foreign substance

111 irradiation region

112 high resistivity region

[Document Name] Abstract

[Summary]

[Subject] The invention is directed to repairing a defective portion caused by a short circuit without generating a dark spot by a pin hole.

[Solving Means] Laser beams are irradiated to an irradiation region 111 set in a peripheral region of a foreign substance 100. This prevents an organic EL element 60 to which the foreign substance 100 adheres from being damaged and prevents a pin hole formation. By irradiating the peripheral region at a distance from the foreign substance 100 with laser beams, the energy of the laser beams spreads concentrically from the irradiation region 111, and is also supplied to the foreign substance 100 indirectly. Therefore, the high resistivity region can be formed between an anode layer 61 and a cathode layer 65 so that a defective portion caused by a short circuit due to the foreign substance 100 can be repaired.

[Selected Figure] Fig. 3